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Evaluation of STEM-Aligned Teaching Practices for Gifted Mathematics Teachers

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ABSTRACT

Background: The STEM education system has garnered significant interest due to its innovative approach in creating a multidisciplinary and integrated knowledge structure that connects science, technology, engineering, and mathematics, and allows students to apply scientific knowledge in a comprehensive and holistic manner. Consequently, evaluating the teaching methods of teachers in accordance with STEM standards is critical. This assessment should take into account various educational objectives, including cognitive, skill-based, and emotional aspects.
Purpose: This study aimed to evaluate the creative teaching practices of mathematics teachers for gifted students according to STEM standards.
Method: The study applied the descriptive analytical method and developed a rating scale for evaluating creative teaching practices based on STEM standards, verifying the psychometric properties in several ways. The study sample consisted of 64 teachers of mathematics for gifted students.
Results: The results showed that the degree of application of creative teaching practices by the teachers of gifted students according to STEM standards was at the moderate level in three domains: planning, implementation, and assessment.
Conclusions: Despite the importance of achieving integration for STEM, the actual teaching practices of teachers of the gifted according to these standards were generally average and did not reach acceptable and ambitious levels.

Keywords: STEM standards, evaluation of teaching practices, gifted students, mathematics teachers

INTRODUCTION

There have been rapid developments in knowledge and huge technological growth in recent decades, requiring educational institutions around the world to try to keep pace with advances in various fields of human and natural sciences. Engaging with these developments is crucial as education is the foundation on which students are prepared for the future. This has led to the search for new and effective methods to develop learners' capabilities in an integrated manner and it has become a priority for educational systems to prepare and enable teachers to employ modern teaching methods. Teachers need appropriate professional development to enhance their competencies so that they can keep up with modern developments and integrate modern educational strategies and approaches in their practice. Teachers have a prominent role in nurturing learners and ensuring future

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generations can meet the requirements of the evolving and changing job market. The world has begun to move towards a new system of learning aimed at coping with global challenges and contributing to solving society's problems by linking various scientific fields (science, mathematics, technology, and engineering design) to life. The STEM education system stands apart from traditional educational systems in that it does not rely on rote memorization and indoctrination, but instead emphasizes creative approaches to learning that are grounded in problem-solving. This is accomplished by situating the problem within a real-world context and working to resolve it. Consequently, the system promotes the cultivation of scientific and practical experience among students in all four fields in an advanced and effective manner. Additionally, it targets students across different levels of primary, preparatory, and secondary education, preparing them for specialized studies in these sciences at the university level. The system also fosters inquiry, analysis, dialogue, critical thinking, and creativity among students, thereby maximizing the benefits and quality of education within the aforementioned fields (Al-Hilali, 2021; Al-Saeed, 2021).

Local and Global Institutional Orientations of Interest in Education That Conform to STEAM Standards

The interest in education that complies with STEM standards is due to a reform movement led by politicians around the world aimed at remedying the effects of the economic recession, based on the belief that preparing students for the future as engineers, scientists, and technicians will contribute significantly to the production of innovative ideas that will in turn lead to economic development. For this type of teaching to be effective, it is necessary to have qualified teachers who have the capabilities to overcome any challenges that they may encounter. Therefore, they must be able to employ the teaching methods and strategies that will result in the desired transformations (El-Baz, 2018).

Those involved in the provision of education locally and globally are focused on ensuring mathematics teachers' practices can meet the challenges of today's mathematics classroom by improving their efficacy and efficiency. Teachers' practices rely on their skills, which are acquired not innate. Thus, it is possible to train teachers in the skills of planning, implementation, and evaluation so that they are equipped to employ effective teaching practices and assure a successful learning experience. Moreover, teachers' continued acquisition and development of these skills, together with experience gained in the classroom over time, can help them address the shortcomings of the curriculum and attain mastery in teaching (Al-Faqih, 2016; Al-Shehri and Atoum, 2018).

Mathematics is characterized by its specific nature in terms of its structure, content, and methods. This subject is considered one of the most important in the curriculum in the contribution it can make to the development of students' thinking. Mathematics is the foundation for learning and developing some sciences and is the language of understanding and exchanging ideas in numerous fields (Kaware, 2017). Mathematics teaching methods have moved away from the traditional approach based on memorization and solving exercises as routine solutions. Modern methods help students to think and discover all possible solutions to each mathematical problem independently and with peers. They aim to develop positive attitudes towards mathematics and employ strategies such as self-learning, discovery learning, problem-solving, and cooperative learning. As noted by Saleh (2006), cooperative learning using a range of educational activities and computer-based tasks is a modern trend in teaching mathematics.

Among the educational objectives of teaching mathematics defined by the United States (U.S.) National Council of Teachers of Mathematics (NCTM) is the integration of science and mathematics. In this regard, researchers and educators have paid increasing attention to developing standards for teaching mathematics in line with modern trends, including STEM education. One of the most important is the standard of interdependence, which concerns linking mathematics to the real world and other fields of knowledge. This criterion entails ensuring that the student sees mathematics as playing an important role in the arts, social studies, and sciences, which requires the continuous integration of mathematics in the various fields of knowledge (Habashneh, 2020). STEM receives the attention of international organizations that seek development and innovation. Therefore, the American Referees Association has called for the introduction of measures to improve the competence of teachers in the field of STEM and to increase the number of students who pursue advanced studies related to it (Al-Ghamdi, 2020).

Learning using the STEM approach is based on a philosophy that involves employing educational activities and projects to help stimulate learners' thinking and enable them to acquire scientific knowledge and apply it in solving problems in real-world situations, eventually achieving a connection between the school, society, and the labor market (Williams and Mangan, 2016). Among the most important justifications for the interest in STEM education are the following (see Carroll, 2015; Koch et al., 2018; Mansour and El-Deghaidy, 2015):

1. It links multidisciplinary scientific content to the life and reality of the learners by presenting the problems and situations experienced by the learners in their community.
2. It allows learners to deal with many technological and engineering applications around them in their environment, which increases their self-motivation to engage in scientific investigation inside and outside science classes.

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3. Students learn through projects, which helps develop scientific research skills and enhances positive attitudes.
4. It enables learners to make assumptions and arrive at scientific verification through the use of modern engineering and technological tools.
5. It contributes to the development of students' mental abilities and different patterns of thinking.
6. It provides students with 21st-century skills and technical design skills.

STEM education is highly important in supporting the goals of educational development in the Kingdom of Saudi Arabia -National Transformation 2020, as it enriches the educational environment with tools that stimulate creativity and with scientific content that functionally links future sciences (Al-Daoud, 2017). The interest in STEM and its application in teaching gifted students came from the congruence between its characteristics and those of gifted students. Many studies have suggested the importance of using an integrated educational approach, which is based on linking the curriculum with various teaching and learning styles and methods. Among the most prominent efforts of the Ministry of Education in Saudi Arabia is the STEM initiative, launched in 2010 within the national strategies for the development of general education (Ministry of Education, 2010).

The Importance of Evaluating the Teaching Performance of Teachers in the Light of Specific Indicators and Evidence for the Use of STEAM in Education

Any reform or development in the educational process must begin with the teacher as the main pillar and active agent in teaching and learning, who plays a key role in determining the quality of the outputs of the educational process. Whatever the quality of the course, and whatever technology and educational media are available, the teacher is the master of the situation in exploiting the resources available to move the hearts and minds of the students. Moreover, it is not possible to realize the product of the process of planning, building, and developing courses without teachers as they are responsible for transforming theoretical plans into class behaviors and good educational practices (Al-Anzi and Al-Jabr, 2017; Al-Qathami, 2017; Obaid, 2004). Therefore, there is a constant need to evaluate teaching performance with reference to modern trends in teaching and learning, the most prominent being the integration of STEM education.

As the STEM approach is centered on developing a scientific culture and the application of knowledge, not teaching separate scientific subjects, it is necessary to identify teachers' attitudes toward this new approach and examine their teaching practices (Hamdi, 2017). The evaluation of teaching includes all the procedures followed by the teacher to ensure that the lesson objectives are attained. In this regard, as pointed out by Al-Shahrani (2013), for the evaluation of teaching and learning to be accurate and objective, the teacher should view it as a diagnostic, preventive, and therapeutic process, undertaken in a developing and continuous manner before, during, and after teaching. It is also a comprehensive process that addresses three aspects of educational goals: cognitive, skills-based, and emotional. It is a collaborative process involving several parties and is based on scientific foundations, such as honesty, consistency, and objectivity. It draws on various methods and tools (tests, observation, interviews, and achievement files). Thus, the concept of evaluation is not synonymous with the concept of assessment through examinations or tests, being much broader and comprehensive.

Given the importance of evaluating teaching performance, many studies have addressed this (Al-Hutaibi, 2018; Al-Roqi, 2018; Salamat and Al-Shehri, 2016), and there are various tools, methods, and strategies for evaluating teachers' practice and performance in the classroom, including note cards, questionnaires, achievement files (portfolios), student evaluations of the teacher, educational supervisor evaluations, peer evaluation (teachers), and teacher self-evaluation (Abdel-Raouf, 2017; Mohammed, 2018; Nasr, 2010).

It is clear from the foregoing arguments that the skills of planning, implementation, and evaluation are among the basic skills of teaching that must be in the repertoire of the teacher and should be developed to contribute to the achievement of educational goals. It is necessary to evaluate science teachers' performance with reference to modern trends in teaching and learning, especially STEM education, because of its importance in developing students' capabilities and skills in line with the requirements of the job market and enabling them to confront the problems and challenges of life in the 21st century. Thus, this study addresses the call for research in this field, by evaluating the teaching practices of middle school mathematics teachers based on the precepts of STEM education.

Evaluating teaching practices based on STEM standards is crucial for improving the quality of education in STEM areas. This evaluation helps identify both weaknesses and strengths in teaching methods, enabling educators to enhance the effectiveness of the educational process and achieve better outcomes for students. Moreover, evaluating teaching practices according to STEM standards contributes to the development of students' critical thinking skills and creativity. When teachers employ strategies that promote critical thinking and creativity, students can hone their problem-solving abilities, foster innovation, and enhance their scientific analysis skills. Furthermore, aligning education with STEM standards through teaching evaluations addresses the demands of the STEM job market. With more countries transitioning into STEM economies, there is a growing need for skilled graduates in these fields. By guiding and developing teaching practices based on STEM standards, students can acquire the necessary skills to thrive in modern STEM careers. Lastly, evaluating teaching practices based on STEM standards emphasizes active learning and the practical application of scientific and technical concepts, fostering a more engaging and effective educational experience for students.

STEAM Education Applications

STEM has been increasingly incorporated into education in recent years, as it is recognized as a valuable approach to prepare students for the workforce and to address societal challenges. Here are some examples of the application of STEM in education. First, STEM education often emphasizes project-based learning, which involves students working on real-world problems in a collaborative and interdisciplinary manner. This approach can help students develop critical thinking, problem-solving, and communication skills (National Science Foundation, 2010). Second, many schools are introducing robotics and coding into their curriculum to enhance students' computational thinking skills and prepare them for careers in technology. For example, the Code.org program offers free coding courses and resources for K-12 students (Muniandy et al., 2022). Third, Maker education involves hands-on learning through making and creating, often using technologies such as 3D printing and circuitry. This approach can help students develop creativity, innovation, and design thinking skills (Halverson and Sheridan, 2014). Fourth, some schools are adopting an integrated STEM approach, which involves the integration of STEM subjects into other subject areas, such as language arts and social studies. This approach can help students see the relevance of STEM in their daily lives and develop a more holistic understanding of STEM concepts, and can improve students' engagement, motivation, achievement in STEM subjects (Breiner et al., 2012). Fifth, Inquiry-based learning is an approach to education that involves students asking questions, investigating problems, and making discoveries, where found that inquiry-based learning in STEM education can improve students' understanding of scientific concepts, and problem-solving and critical thinking skills, as well as their ability to ask and answer scientific questions (National Research Council, 2012). Sixth, STEM Career Preparation: STEM education is often seen as a way to prepare students for careers in STEM fields. O'Brien et al. (2017) found that providing high school students with STEM internships can improve their understanding of STEM careers and increase their interest in pursuing STEM fields. Seventh, Professional development is an important factor in the success of STEM education, as STEM teachers need to be prepared to teach STEM subjects effectively. Research by Gardner et al. (2019) indicates that providing professional development to STEM teachers can enhance their content knowledge and pedagogical skills. Eight, STEM education has been linked to improved academic achievement, particularly in mathematics and science, this is confirmed by Wang et al. (2018) that participating in STEM programs can improve students' academic performance and academic achievement in mathematics and science.

Previous Studies

Professional development programs that focus on STEM content and pedagogy can improve teachers' knowledge and skills, which can positively impact student achievement (Banilower et al., 2013). Hurd and Bouwma-Gearhart (2013) found that classroom observation can be an effective tool for evaluating STEM teachers when done in a collaborative and supportive manner that focuses on teacher growth and development. The study by Kennedy et al. (2014) showed that teacher quality has a significant impact on student achievement in STEM subjects, and that teacher evaluation systems should incorporate measures of student achievement to provide a comprehensive evaluation of STEM teachers. According to Goldhaber and Theobald (2010), peer evaluation provides a collaborative, supportive, and reflective approach to evaluating STEM teachers, which can be a useful way of evaluating their performance and promoting their growth and development. According to a study by Loughran (2014), self-evaluation can be a useful tool for STEM teachers to evaluate their teaching practices, as it allows for a reflective and critical approach to teaching that focuses on teacher growth and development. The study by Schunn et al. (2017) found that rubrics can be an effective tool for evaluating STEM teachers, as they provide a clear and objective framework for evaluating teacher performance. Further, Eddy et al. (2015) conducted a study that found that student evaluations can provide valuable feedback for STEM teachers, as they allow for a student-centered approach to teacher evaluation that focuses on student learning outcomes. According to a study by Tschannen-Moran and Hoy (2001), teacher self-efficacy can significantly affect both teaching effectiveness and STEM student accomplishment. According to a study by Grunspan et al. (2018), teacher collaboration provides a collaborative and supportive approach to teacher evaluation that focuses on teacher growth and development, which can enhance teacher performance and student accomplishment in STEM courses. Learning communities offer a collaborative and supportive approach to teacher evaluation that focuses on teacher growth and development, according to a study by Darling-Hammond et al. (2017). This method can increase teacher performance and student achievement in STEM courses. According to a study by Darling-Hammond et al. (2012),

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differentiated assessment, which offers a customized approach to teacher evaluation and focuses on teacher growth and development, can increase teacher performance and student accomplishment in STEM courses.

The study by Alghamdi and Alghamdi (2018) highlighted the need for more research and development in gifted education in Saudi Arabia, as well as the importance of providing appropriate educational opportunities for gifted students. Al-Hilali (2020) conducted a study to examine the opinions of gifted students and science teachers in Saudi Arabia on teaching with STEM standards. The findings revealed that STEM-based science instruction led to high satisfaction levels among gifted students and had a positive and significant impact on their academic performance. According to the study by Al-Ghuwairi and Al-Sharaa (2017), a low percentage of science teachers incorporate scientific experiments in their teaching of gifted students. Kanli and Özyaprak (2015) conducted a study that demonstrated how educational institutions offer opportunities for gifted students to advance their studies in higher levels and engage with experts in the fields of science, technology, engineering, and mathematics.

The study by Guo et al. (2021) found that teaching quality significantly predicts student engagement, which in turn positively affects academic performance. The study by Aljohani et al. (2021) identified the factors that affect the quality of teaching in higher education in Saudi Arabia. It also suggests that faculty development programs and instructional technology are important factors that contribute to teaching effectiveness. The study by Sung and Lee (2019) used data from the Trends in International Mathematics and Science Study (TIMSS) to examine the effects of teacher quality on student achievement in mathematics and science. The authors found that teacher quality significantly affects student achievement, and that teachers' content knowledge, pedagogical skills, and classroom management practices are important factors that contribute to teaching effectiveness.

Study Problem

The United Nations Development Program (UNDP, 2014) pointed to major difficulties and challenges facing education and the workforce in the Arab region in general, and in the Kingdom of Saudi Arabia specifically, in particular concerning the mismatch between the outputs of education and the job market. Furthermore, the results of the latest Trends in International Mathematics and Science Study (TIMSS) in 2015 showed that the Kingdom of Saudi Arabia had low scores for tests in the primary and intermediate stages (Ministry of Education, 2018).

Several studies have shown that STEM education is effective in addressing problems and challenges in the field of science and mathematics education (Akaygun and Aslan-Tutak, 2016; Bakırcı and Karışan, 2017). The U.S. National Research Council (NRC, 2011) highlighted that it develops the ability of learners to solve problems in realistic contexts through projects in which the learners simulate scientific methods of processing and producing knowledge. Research studies and conferences have advocated teacher development that addresses the integrated approach offered by STEM education. It is also recommended that STEM programs for professional development be designed based on international standards, such as those of the NRC, NCTM, International Society for Technology in Education (ISTE), and International Test and Evaluation Association (ITEA) (Lantz, 2009). In Saudi Arabia, the First Excellence Conference in Teaching and Learning Science and Mathematics: STEM, held at King Saud University in 2015, recommended conducting more research to describe the practices and performance of Saudi teachers and develop the necessary programs to improve STEM teaching in the general education program in the Kingdom (The Excellence Research Center of Science and Mathematics Education ECSME, 2015).

There have been numerous studies on the application of STEM education in teaching and learning. Cinar et al. (2016) found that the STEM approach was successful in providing learners with different skills, enabling them to innovate and think logically, as well as increasing their self-confidence in solving problems. In Honey et al.'s (2013) study, the learners participated in a variety of activities, including some related to engineering innovation and project design. The study showed the success of this program in achieving its objectives and recommended that the program be used for training and preparing teachers for STEM education. Fang (2014) also showed that students who engaged in a motivational program to arouse their interest in the field of STEM showed positive attitudes toward the program. The study suggested that trainers in STEM programs include a brainstorming method to make teaching this field more effective and at the same time enhance the exchange of ideas among learners (Fang, 2014).

In the Arab context, Al-Dosari's (2015) study, which analyzed the status of STEM education in Saudi Arabia with reference to international experiences, recommended conducting pre- and in-service rehabilitation and training programs to qualify and train science and mathematics teachers in the Ministry of Education on STEM education. Malaka (2018) highlighted that Arab Gulf countries need a labor force with the science, technology, engineering, and mathematics skills relevant in the 21st century to be able to move from an oil-based economy to a knowledge-based economy and attain integration with the global economy; to this end, educational institutions must develop curricula that are in line with STEM standards. Al-Rouqi (2018) recommended undertaking in-service evaluation of the performance of teachers. Murad (2014) found a deficit in the teaching skills of female teachers consistent with the STEM approach.

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Some studies have identified the effectiveness of the STEM approach in improving the educational process (Al-Saeed, 2021; Kutch, 2011). Others have highlighted teachers' positive attitudes toward using the STEM approach in teaching (Park et al., 2016). Many studies have addressed the obstacles to applying STEM education and have shown that the key issues are related to the teacher and the need for training (Alyan, 2020; Al-Salahi, 2019). Given the pivotal role of the teacher in the educational process and the shift from being a provider of information to a guide and facilitator, teachers now need a greater and different range of educational competencies, as confirmed by Habashneh (2020), who also argued for training mathematics teachers in the teaching strategies appropriate to implement the integrated STEM approach.

The importance of scientific materials for the education of gifted students cannot be overstated, especially in the fields of Science, Technology, Engineering, and Mathematics (STEM), which are crucial for maintaining global leadership, stimulating economic competitiveness, and ensuring long-term success. Furthermore, education plays a key role in helping students achieve self-realization, which is deemed a highly important outcome of education (Matthews, 2014). Gifted students are often drawn to science subjects due to their excitement and suspense. As a result, the Kingdom of Saudi Arabia places significant emphasis on the development of the STEM approach, calling for its integration into schools and universities. STEM education provides a significant opportunity to motivate talented individuals, and helps them develop their scientific, analytical, and innovative skills. The Saudi government has implemented various initiatives and programs, such as the Tomouh Program, National Robot Challenge Program, and Invention and Innovation Program, aimed at developing the skills and abilities of talented individuals in STEM fields through practical training, workshops, research projects, and other educational activities (Madani, 2020; El-Deghaidy and Mansour, 2015).

Despite the Saudi Arabian government's emphasis on the importance of implementing the STEM approach in education, Al-Hilali's (2020) study revealed that science instruction for gifted students in Saudi Arabia falls short of the standards of the STEM approach, relying heavily on rote memorization and achievement tests. Studies like this one have spurred researchers to explore the feasibility of adopting the STEM approach in teaching practices, as well as its implications for gifted students in the classroom. Notably, this study was conducted by a research team that included members from the National Center for Research on Giftedness and Creativity, an organization affiliated with the Saudi government that is tasked with conducting research and field studies in the area of gifted education.

Based on the above, this study sought to evaluate the teaching practices and performance of mathematics teachers for gifted students according to STEM standards and addressed the following questions:

1. What are the teaching practices required for teachers of mathematics for gifted students in the intermediate stage of education in line with STEM standards?
2. What is the actual level of implementation of teaching practices consistent with STEM standards by mathematics teachers for gifted students in the intermediate stage of education?

Significance of the Study

One of the primary goals of implementing the STEM approach is to cultivate students' creativity and innovation skills, encourage them to think beyond the box, and engage them in solving authentic problems. This is achieved by emphasizing analytical and critical thinking skills and promoting teamwork through interactive and enjoyable projects, as opposed to relying solely on theoretical lectures. Consequently, assessing the teaching practices of educators and their impact on student learning provides valuable insights and indicators into the degree to which the aforementioned objectives have been attained.

The STEM approach offers educators an opportunity to develop and enhance their skills and expertise, which in turn can lead to improved employment prospects, effective communication with students and colleagues, and the ability to work collaboratively. Furthermore, it can have a positive impact on both students and society as a whole. Therefore, it is crucial to investigate the extent to which teachers integrate STEM standards into their educational practices, and the effectiveness of these practices in enhancing the learning and achievement of gifted students in STEM subjects. Additionally, verifying the level of access that educators have to the skills and knowledge required to teach these subjects effectively is essential in this regard.

Conducting ongoing evaluation processes for the various aspects of the STEM approach is essential to determine its success and sustainability. Among these aspects, the teaching practices of educators within classrooms are particularly significant and require continuous evaluation. Only by assessing the effectiveness of these practices can the overall success of the STEM approach be accurately evaluated and optimized for sustained success.

Assessments of creative teaching practices within gifted education are crucial because they significantly enhance the learning experience of gifted students. These evaluations promote deep thinking, foster creativity and innovation, offer appropriate challenges, encourage active learning and collaboration, and contribute to advanced academic achievement. By engaging in these practices, gifted students develop crucial skills in analysis, critical

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thinking, creativity, problem-solving, communication, and teamwork. Furthermore, these practices ensure that individual academic needs are met and that a stimulating learning environment is provided to cultivate talents and enable gifted students to achieve their full potential.

The Kingdom of Saudi Arabia has invested significant financial resources in the design of curricula and training programs for educators in line with the STEM approach. As such, the Kingdom aims to identify the learning outcomes and value added by implementing this approach. This is particularly important to meet the educational requirements of gifted and talented students, and to develop effective teaching programs and approaches. To this end, conducting an evaluation study on the teaching practices of educators and their impact on student learning is crucial. Through this evaluation, important insights and indicators can be gained regarding the effectiveness of the STEM approach in meeting the unique educational needs of students.

THEORETICAL FRAMEWORK

STEM education arose in the U.S. in 2001 in response to the problem of students' weaknesses in science and mathematics. Moreover, it offered a way of linking education to daily life, presenting students with the opportunity to develop concepts and skills in a comprehensive and integrated manner through problem-solving and working on projects from real life. This would bring the various fields of study together to form an educational system for the primary and secondary stages that integrated science, technology, engineering, and mathematics and encouraged creative and innovative learning to solve problems and apply learning in practice (Kaware, 2017).

The most important characteristic of the STEM approach in our opinion is that it draws on practice, exploration, and experience formed through trial and error, which allows students to create links between different topics, raise questions, and explore their answers. Thus, one of the most effective ways of implementing it is to use real-life examples so that children can gain an understanding of the applications of the concepts and processes. STEM standards provide the framework for applying this approach effectively when teaching students. As noted by Al-Qadi and Al-Rabiah (2018), STEM standards are based on the integration of content and a set of behaviors expected of gifted and talented students, including participation, logical thinking, cooperation, and research. There are seven STEM standards that define the basic elements of learning and skills needed by gifted students in the fields of science, technology, engineering and mathematics, and the formulation of STEM standards moves in a coherent and sequential direction as follows (Al-Ghamdi, 2020; Al-Qadi and Al-Rabiah, 2018):

Standard 1: Link technologies to learning and application of concepts
Standard 2: Integration of these concepts into a single framework and path.
Standard 3: Interpret, analyze, critique, and monitor sources of learning outcomes
Standard 4: Validate concepts, validate concepts objectively
Standard 5: Engage in logical reasoning by employing critical thinking
Standard 6: Work as a team to examine learning and application outcomes
Standard 7: Improvement, refinement, and application of technology.

Education Philosophy Underpinning STEM Education

The philosophy underlying STEM curriculum, in our opinion, is characterized by flexibility, so it can contain and integrate all the aspects that serve the interdependent approach to engaging with science, mathematics, technology, and human activities (Al-Hilali, 2021). Education according to the STEM system depends on presenting a problem or challenge to the students on which they then work in collaborative teams, employing specific tasks to search for additional information from reliable sources, deepen knowledge and understanding, and make links between different disciplines. They then analyze the information, classify it, and present hypotheses to plan and design proposed models for experiments. They identify the necessary materials and tools and then work to implement and apply the proposed ideas and solutions. They present their solution to the problem presented in the challenge to the target group and peers to obtain feedback that will enable them to improve their operations and performance (Al-Moumani and Jaradat, 2019).

Objectives and Benefits of STEM Education

The general goal of learning according to the STEM philosophy in our opinion, is to link learning to life or reality. Science education has many important objectives that can help students develop their skills and knowledge in various areas. One of these objectives is to increase students' cognitive curiosity towards discovery, investigation, and knowledge of the dimensions of their world. By doing so, science education can help students develop a natural curiosity and a desire to learn more about the world around them. Another important objective is to raise students' level of confidence in science concepts by applying and employing them in explaining phenomena and solving problems surrounding them. This can be achieved through various teaching methods, such as hands-on learning

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experiences, real-life applications, and problem-based learning activities. To achieve these objectives, science education should also provide students with various thinking skills, the most important of which are design thinking, problem-solving, and decision-making. (Omar and Al-Qahtani, 2022; Alyan, 2020; National Science Foundation, 2010).

In our perspective, STEM education offers numerous benefits for students across various age groups and backgrounds. STEM education fosters the development of creativity by encouraging students to think innovatively and utilize their diverse skills and competencies, thereby enhancing their creative thinking abilities. STEM education offers a range of benefits for students across different age groups and backgrounds. Firstly, it enhances self-confidence by providing students with authentic learning experiences where they can express their ideas and solutions, leading to increased self-esteem. Secondly, STEM education develops problem-solving skills by encouraging students to tackle societal challenges using scientific and creative approaches. Additionally, it fosters collaboration as students work in teams to solve problems or complete projects, cultivating skills like critical thinking and teamwork. Moreover, STEM education supports success and achievement, particularly benefiting gifted students. It also aligns with 21st-century advancements, leveraging technology and information revolution. Lastly, STEM education promotes logical reasoning across mathematics, science, technology, and engineering, contributing to the development of analytical and problem-solving abilities (Al-Hilali, 2021; Al-Ghamdi, 2020; National Research Council, 2011).

Modern Teaching Strategies Appropriate to STEM Trends

Modern teaching strategies have paid great attention to learners, their nature, needs, and interests. They also draw on various theories and laws of education and examining these strategies shows adherence to many modern educational principles, such as putting the learner at the center of the educational process. One of the most important strategies for teaching is implementing activities in which the learner plays the main role, and the role of the teacher is limited to guidance and counseling, not indoctrination. These methods and strategies emerged through the development of educational and social philosophical thought and in response to educational psychology theories (Attia, 2008; Hamdi, 2017; Ryan, 1999).

Choosing the Best Strategy for Teaching Based on STEM Standards

Choosing the best strategy for teaching a particular subject that combines different sciences is a complex and multidimensional process. To succeed in choosing such a strategy among the many existing strategies, the following steps can be followed (Al-Hilali, 2021; Shaheen, 2010); first, get to know as many strategies as possible. Second, determine the strategies that fit the topic or content of the lesson. Third, identify the strategies that would make it possible to achieve the objectives of the lesson. Fourth, determine the strategies that are in line with the characteristics of the students. For instance, if students excel in dialogue and discussion, opt for a strategy that encourages discussion. By following these steps, educators can make informed decisions when selecting teaching strategies that best suit the subject matter, lesson objectives, and student characteristics.

Criteria for Selecting Teachers of Gifted Students and Identifying Their Training Needs According to the STEM Approach

STEM teachers are expected to meet precise standards, as outlined by Al-Hilali (2021) and Saada (2010). This includes a profound understanding of cognitive, theoretical, historical, and social foundations that impact the development of gifted students and creating educational environments conducive to their unique needs. Teachers must employ diverse teaching methods and strategies, emphasizing student-centered approaches that empower learners to take charge of their education under expert guidance. They should design appropriate learning environments tailored to gifted students, fostering meaningful social interactions. Effective communication methods that resonate with gifted students are crucial, encouraging activities aligned with their abilities and needs. Additionally, teachers should adeptly design study plans and employ evaluation methods tailored to the educational needs of gifted learners. Extensive experience in gifted education and a commitment to ethical practices are also essential components of effective STEM teaching for gifted students.

As noted by Jarwan (2013), training teachers to raise their level of performance, competencies, and skills in teaching gifted students is a developmental process that requires sufficient time if it is to benefit those teachers who have the requisite behavioral traits and personal characteristics for success. Thus, it is not possible to deploy teaching consistent with STEM standards successfully and effectively except through training.

The preceding section provided an overview of the core dimensions of the STEM approach, encompassing its origins, aims, and underlying philosophy. It emphasized the significance of selecting the most appropriate teaching strategies aligned with STEM standards, as well as establishing criteria for recruiting and identifying the training requirements of teachers in accordance with the STEM approach. These theoretical dimensions served as a

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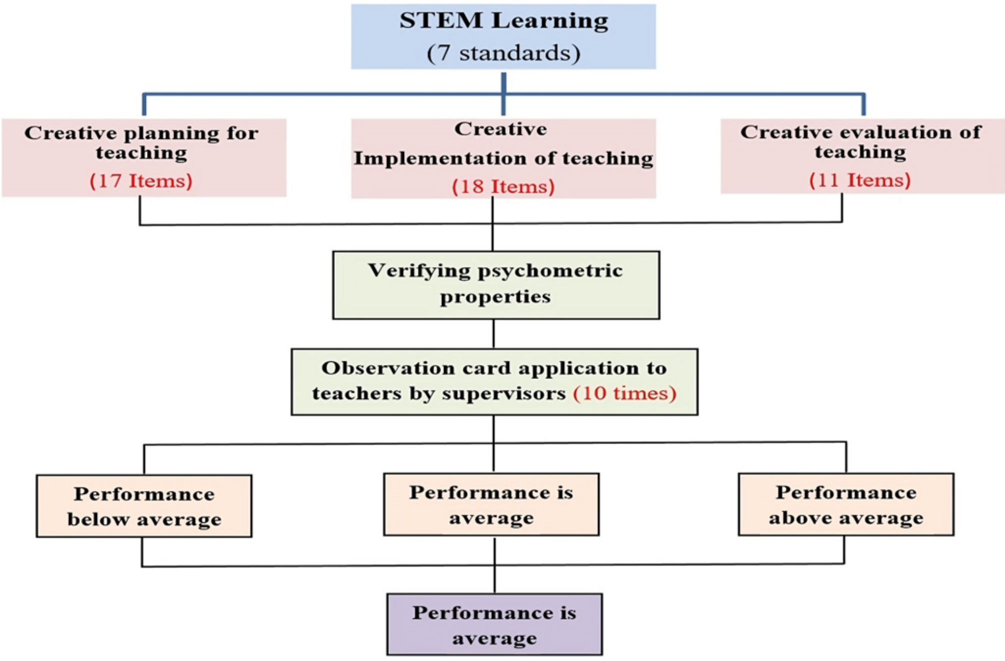

Figure 1. Research procedures

precursor to the philosophical frameworks, foundations, and standards for teaching strategies, assessment methods, and teacher roles. This, in turn, facilitated the development of a rating scale for teachers' teaching practices based on the STEM approach.

METHODOLOGY

This study utilized a descriptive analytical approach, aimed at quantitatively describing the phenomenon under investigation by assigning scores that reflect actual performance levels. The analysis relied on quantitative results to enhance understanding, diagnose the current state, and draw conclusions. Furthermore, the research investigated the practical implementation of teaching strategies among mathematics educators in the context of STEM orientation. The rating scale was developed based on STEM standards to evaluate teachers' instructional practices aligned with STEM principles.

Population and Sample

The study population consisted of all teachers of mathematics for gifted students in government schools in the eastern region of Saudi Arabia in the academic year 2022/2023. The selection of gifted students was conducted following their participation in several programs, including the National Gifted Identification Program, Mawhiba Enrichment Programs, Research and Innovation Development Programs, the National Olympiad Program for Scientific Creativity, and the Mawhibah Advanced Program in Science and Mathematics. The study sample consisted of 64 teachers of mathematics for gifted students, who were selected randomly from (16) schools in which there are classes for gifted students. Eight educational supervisors were selected in the light of specific criteria, the most important of which are professional and academic experiences in this field, in order to evaluate the teaching practices of teachers using the rating scale constructed for this purpose.

Study Instrument

Based on a review of the literature and previous research, the researchers prepared a list of teaching practices that middle school mathematics teachers need to implement STEM standards and a rating scale was constructed to estimate the level of teaching practice aligned with STEM standards (STEM) among middle school mathematics teachers.

Study Design

The creation of a research design is a crucial aspect of scientific research as it allows for the careful selection of suitable research methods, data collection, and interpretation procedures. Figure 1 shows the study design procedures.

Steps in Designing and Constructing the Study Instrument

First, the researchers prepared a list of the most important teaching practices appropriate to the STEM standards that teachers of mathematics for gifted students need after reviewing the literature and previous studies that dealt with STEM education. These variously considered the concept, philosophy, importance, goals, principles, foundations, standards, strategies, methods of evaluation, educational activities, learning and teaching resources, the roles of the teacher and the learner, as well as preparation of STEM teachers and STEM schools (Abdel Salam, 2019; Al-Hilali, 2020; Al-Jalal and Al-Shamrani, 2019; Al-Shammari, 2017; Elbez, 2017; Hamdi, 2017; Jolly, 2015; Kaware, 2017; Koppes, 2015; Koussa and Ba-Yones, 2019; Omar and Al-Qahtani, 2022; Saber, 2019).

The literature agrees on the most prominent areas of evaluating teaching practices, namely planning, implementation, and evaluation (Al-Moumani and Jaradat, 2019; Al-Omari and Asiri, 2018; Bayoumi and El-Gendy, 2019; Ibn Quwaid and Al Salem, 2019). Based on the previous literature, we identified a list of principles and standards for STEM education to be used in determining the teaching practices and performance mathematics teachers of gifted students would need to deploy in class to attain the objectives of teaching mathematics in accordance with STEM standards. The list consisted of 46 practices or aspects of teaching performance classified into 3 dimensions: planning for teaching in accordance with STEM standards (17 practices), implementing teaching in accordance with STEM standards (18 practices), and evaluating learning in accordance with STEM standards (11 practices). These are presented in **Table 1**.

Table 1. Most significant teaching practices appropriate to STEM standards

Field		Teaching practices
Creative planning for teaching using STEM approach	1	Determine the cognitive, skills-based, and emotional needs of learners to meet STEM standards
	2	Plan educational objectives in a way that shows the integration of mathematics, science, engineering, and technology
	3	Organize the content in a way that shows the integration between mathematics, science, engineering, and technology
	4	Plan content in a problem-solving manner to suit the level of learners
	5	Plan and design lessons to achieve the objectives of STEM education, such as: developing thinking and technological skills, encouraging teamwork, communication, scientific investigation, scientific experimentation, self-learning, and technological and engineering design
	6	Determine various appropriate teaching strategies for STEM education, such as: scientific inquiry, problem-solving, self-learning, active learning, metacognition, differentiated learning, play-based learning (e.g., using robots and Lego), project-based learning, brainstorming, experimentation, scientific reasoning, cognitive journeys, and learning cycles
	7	Design enrichment, investigative and exploratory activities
	8	Plan engineering designs to solve problems in mathematics
	9	Plan educational situations that link the content of science, technology, engineering, and mathematics to the reality of the learners' lives
	10	Plan for learner-centered learning and consider individual differences among learners
	11	Plan project-based learning
	12	Ensure diversification in the design and selection of tools and methods for evaluating the knowledge, skills, and attitudes of learners, such as: achievement tests, thinking tests, achievement profiles, attitude and tendency measures, diagnostic concept tests, performance measures, self-evaluation, and peer evaluation
	13	Plan to use the different types of calendars (tribal, formative, and final)
	14	Plan to evaluate different aspects of learning sciences (cognitive, skills-based, and emotional)
	15	Plan investigative tasks that can be carried out by learners at home through research and the use of technological means in various fields of knowledge (the Internet, scientific books, and scientific journals)
	16	Raise exciting questions that help recall previous knowledge, and link and explore relationships between different sciences
	17	Provide an environment based on exploring knowledge from a variety of sources, and conducive to design and innovation
Implementing creative teaching using the STEM approach	1	Prepare for teaching mathematics using a variety of methods suitable for STEM education, such as: a puzzling question, a problem related to students' lives, some contradictions, real events, stories, or open-ended questions. Aim to arouse learners' interest, increase their motivation, and draw their attention to the new lesson
	2	Ask questions that determine the learners' previous experiences related to the subject of the lesson and develop scientific thinking
	3	Allow students the freedom to discuss and exchange ideas through the process of research and inquiry
	4	Employ cooperative learning methods consistent with STEM education
	5	Employ methods of communicating with the community consistent with STEM education
	6	Employ scientific investigation consistent with STEM education

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Table 1 (Continued).

Field		Teaching practices
Implementing creative teaching using the STEM approach	7	Employ engineering design consistent with STEM education
	8	Employ problem-centered learning consistent with STEM education
	9	Employ learner-centered learning consistent with STEM education
	10	Employ learning based on applied and technological projects
	11	Direct the students toward the implementation of enrichment, investigative and exploratory activities
	12	Develop 21st-century skills (creative thinking skills, critical thinking skills, life skills, cooperation and communication skills, vocational skills, and technological skills) among learners
	13	Provide scientific and technological tools and resources to help learners solve problems
	14	Create an interactive learning environment that helps research and investigation through a range of activities (investigative activities, discovery and experimentation, and cooperative learning)
	15	Take into account individual differences among students in the teaching and learning process
	16	Use audio and visual samples related to the reality of the learner and employ tools and equipment
	17	Develop research skills and provoke ideas and solutions
	18	Scientifically answer the learners' questions
Holistic assessment based on STEM education	1	Use performance-based continuous assessment consistent with STEM education
	2	Use pre-, constructive, and summative assessment types in teaching consistent with STEM education to verify cognitive growth and learning continuity
	3	Use types of delayed and immediate feedback when teaching consistent with STEM education
	4	Use various evaluation methods and tools in evaluating learners' learning (achievement tests, reasoning tests, achievement profile, attitude and tendency measures, diagnostic concept tests, performance measures, self-evaluation, peer evaluation) consistent with STEM education
	5	Use electronic evaluation methods (electronic achievement files, short tests, discussion boards, blogs, interactive worksheets) consistent with STEM education
	6	Diagnose learners' strengths in learning mathematics consistent with STEM education
	7	Enhance learners' strengths in learning mathematics consistent with STEM education
	8	Diagnose weaknesses in learning mathematics among learners consistent with STEM education
	9	Address deficiencies in learners' learning of mathematics consistent with STEM education
	10	Use methods to ensure the correctness of the solution in mathematical problems
	11	Measure students' abilities to think scientifically consistent with STEM education

Secondly, to measure the level of practice and teaching performance of mathematics teachers for gifted students in the middle school according to science, technology, engineering, and mathematics (STEM) standards in the domains of: planning, implementation, and evaluation, a scale was construct to measure mathematics teachers' practices according to a five-point Likert scale, where the degree of practice is estimated for each items as follows: (5 = very high, 4 = high, 3 =medium, 2 = low, 1 = very low; the maximum score is 230, and the minimum score is 46).

Procedures for Applying the Rating Scale

A training session was organized for both the authors and supervisors, focusing on the proper utilization of the rating scale. During the workshop, the participants were instructed on the correct method of employing the rating scale and were also provided guidance on how to address any potential gaps that they may encounter while implementing the card. Subsequently, a pilot study was conducted by both the supervisors and authors to ensure proper control of the application process.

After preparing the checklist and confirming its validity and reliability, eight supervisors applied it in evaluating mathematics teachers' practices in classes for gifted students over one semester. Each supervisor observed 8 teachers 10 times over the semester. The supervisor will allocate a score ranging from 1 to 5 to each teaching practice employed by the teacher. The teachers would apply certain practices in different classes according to the nature and requirements of the lesson; it would not be necessary or logical to apply all these practices in one class. Accordingly, the final score was based on the average score for the observed and applied practices, and not the average score in the 10 observations. For example, if the teacher applied a particular practice during the semester and repeats it three times, the average was the sum of the scores for this practice divided by three, as shown in the model below which is shown in **Table 2**. The concept of the average level, concerning the degree of application of creative educational practices, aims to gauge how closely the study sample approaches the midpoint of various elements within each dimension of acceptable teaching practices. The study identified creative teaching practices within a spectrum encompassing levels such as very low, low, medium, high, and very high. This categorization serves to assess the proximity of the study sample to achieving a moderate level of implementation across different elements within each dimension of teaching practices.

Table 2. Observation scorecard

Practice	Observation score										Mean	SD	Practice level
	O1	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**O8**	**O9**	**O10**			
Practice 1	1-5	1-5	1-5	1-5	1-5	1-5	1-5	1-5	1-5	1-5			
Practice 2													
Practice 3													
Practice 4													
…													
Practice 46													
Authors' own elaboration													

Note. O: Observation; SD: Standard deviation

Table 3. Person and item separation and reliability for instrument

	Score	Count	Measure	Error	Infit		Outfit	
					MNSQ	**ZSTD**	**MNSQ**	**ZSTD**
Mean	171.7	10.0	1.68	.22	1.05	-.6	1.07	-.5
SD	35.9	.0	2.17	.13	.68	3.5	.71	1.9
Real RMSE	.64							
Adjusted SD	2.08							
Separation	3.25							
Person reliability	0.91							
Mean	189.2	46.0	.00	.06	1.00	-.2	1.07	.1
SD	32.3	.0	.32	.00	.19	1.7	.42	1.8
Real RMSE	.11							
Adjusted SD	.29							
Separation	3.62							
Item reliability	0.95							

Note. SD: Standard deviation; RMSE: Root mean squared error

Verifying the Psychometric Properties of the Rating Scale

To verify the face validity of the scale, the scale was presented to nine raters from experts, including: educational supervisors and faculty members at universities who specialize in: curricula, teaching methods, measurement and evaluation, and they were asked to review the scale's items to ensure the relevance of each items to the domain to which it belongs, and the suitability of the scale to achieve its objective, and the suitability of the items for the study sample. The result of the judgment concluded that it was necessary to rephrase some of the items, and that there was agreement between the raters on the suitability of the scale and the items to measure what it was prepared for. The agreement rate of 80% was adopted as a criterion for agreement between the raters, and the scale was considered valid and appropriate for use in the study.

To verify the reliability of the scale, the scale, consisting of 46 items, was piloted in its final form on a pilot sample consisting of 10 teachers who teach gifted students in mathematics, and from those other than the study sample. The coefficient of agreement was calculated between the estimates of two raters from the researchers, and independently using the Kappa agreement coefficient. The value of the inter-rater reliability coefficient of agreement was (0.93), and this value is considered an indicator of the reliability of the estimate for the scale used by the researchers.

The person and item reliability using Rasch measurement model

To confirm both person reliability (the results of the supervisors' application of the rating scale), and item reliability, a Rasch model analysis was conducted using Winsteps software version 3.68.2. This approach was adopted due to its ability to generate estimated values for both individual ability and item difficulty and discrimination coefficients. Person reliability was employed to assess the reliability of the rating scale, which determines the consistency of supervisors' evaluation results when using the rating scale. Additionally, item reliability was calculated to ascertain the reliability of items within the rating scale. The reliability criteria require a minimum of 50% for reliable results, and a value of more than two for person separation is considered acceptable (AlAli and Al-Barakat, 2022). As presented in **Table 3**, the person reliability values surpass 0.5, with values of 0.91 and 0.95, respectively. Moreover, the person and item separations exceed 2, with results of 3.25 and 3.62, accordingly. The high levels of reliability of the rating scale, based on the Rasch model, are demonstrated by these reliability values.

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Table 4. Indicators and coefficients of construct validity

Constructs	Items	Loading Factor	McDonald's ω	CR	AVE	$\sqrt{AVE}$
Creative planning for teaching accordance with STEM education	10	0.60–0.84	0.935	0.936	0.595	0.772
Implementation of creative teaching in accordance with STEM education	10	0.77–0.91	0.959	0.959	0.705	0.837
Holistic assessment in accordance with STEM education	10	0.65–0.85	0.929	0.929	0.570	0.755

Table 5. Results of exploratory factor analysis using the Promax method

Component	Initial Eigenvalues		
	Total	% or Variance	Cumulative %
Creative planning for teaching in accordance with STEM education	26.774	53.548	53.548
Implementation of creative teaching in accordance with STEM education	2.169	4.337	57.885
Holistic assessment in accordance with STEM education	2.003	4.007	61.892

Indicators and coefficients of construct validity

McDonald's omega and composite reliability (CR) are common methods for determining the reliability of observation instruments. The results in **Table 4** show values for McDonald's omega in the range 0.897–0.956 and for CR in the range 0.899–0.959, which are in line with the recommended value (> 0.7), indicating that the rating scale has considerable internal consistency. Second, the average variance extracted (AVE) values are in the range 0.503–0.705, which is greater than 50%. In terms of discriminant validity, the final column of **Table 4** shows that the square root of the AVE is greater than the minimum value of the loading factor, as required. Therefore, these results demonstrate that the rating scale is reliable and valid.

Construct validity based on factor analysis

To verify the construct validity of the rating scale, we used exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) in SPSS and Amos statistical software. For EFA, we carried out principal components analysis of sample responses to the 46 items in the final rating scale and implemented oblique rotation using the Promax method for the factors extracted with an eigenvalue greater than 1. **Table 5** shows the results of the EFA using the Promax method.

Table 5 shows the presence of 3 factors with an Eigenvalue greater than 1and explained 61.892% of the variance in the total sample. The eigenvalue of the first dimension reached (26.774) and it is a high value compared to other values. The ratio of the first Eigenvalue to the second Eigenvalue is about (12.3) which is greater than 2. This is an indication of unidimensionality. The explanatory variance ratio for the first factor (53.548) is greater than 20%. This is an indication of unidimensionality. It also notes the significant difference in the value of the first Eigenvalue and the second Eigenvalue.

To verify factorial construct validity, we applied the final version of the rating scale with the study sample to conduct CFA of the items within their dimensions. The model described the relationship of the 46 rating scale items distributed over 3 dimensions, we needed to know the loading values of the items on their dimensions in EFA. The factor loading values had to be no less than 0.40 (AlAli and Al-Barakat, 2022) for the items to be included. **Figure 2** shows the results of confirmatory factor analysis that the loading factors of the items were greater than 0.40 within their respective dimensions. Thus, the rating scale retained the three dimensions and associated items. The first dimension contained 17 items, the second dimension 18 items, and the third dimension 11 items.

Figure 2 shows a high degree of factor loading for each item on its dimension. The results also show a strong correlation between the dimensions of the rating scale. **Table 6** presents the indicators of internal construct validity (AlAli and Saleh, 2022), which confirm the CFA results. **Table 6** also shows that the model presents a good fit between the rating scale items and indicators of a good fit the scale in its final form (46 items) with the data of the study sample. Finally, it confirms that all indicators meet the criteria used in this study, indicating the stability of the model of the relationships between the rating scale items.

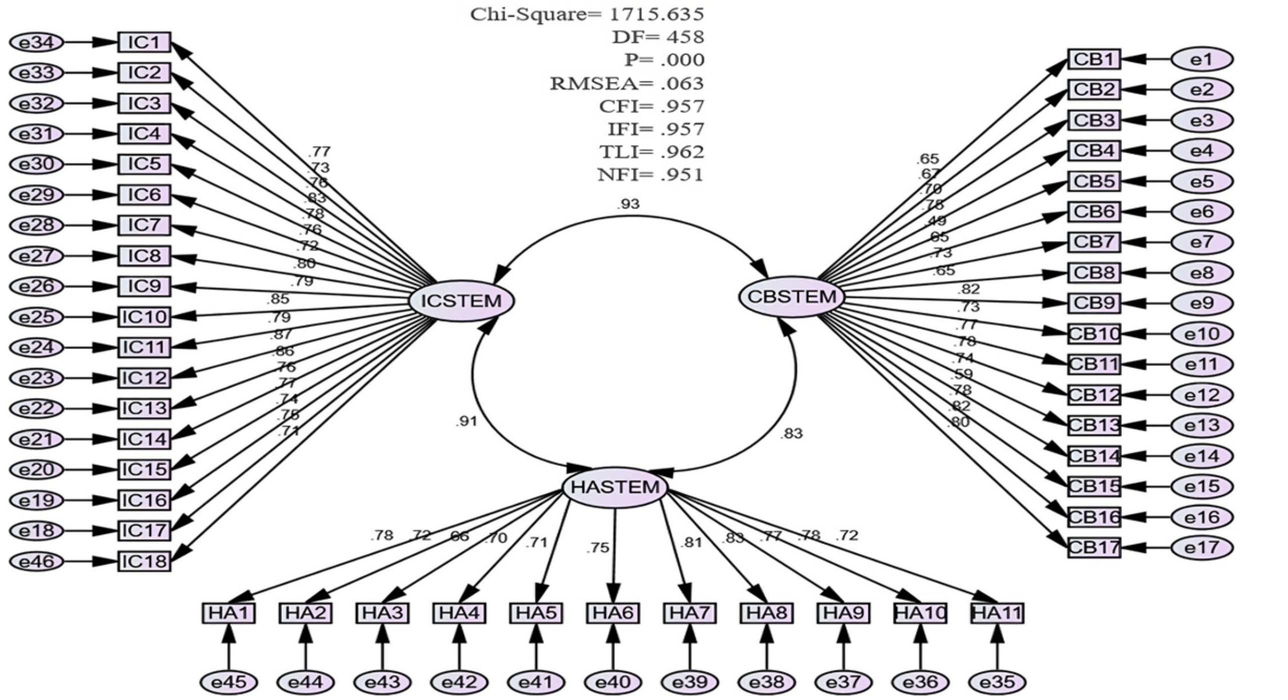

Figure 2. Results of confirmatory factor analysis of the model examining the relationship between the rating scale items and their dimensions

Table 6. Results of confirmatory factor analysis of the model examining the relationship between the observation checklist items and their dimensions

Category	Indicators of internal construct validity	Level of acceptance	Indexes in the proposed model
Absolute fit	χ^2	p > .05	Significant
	RMSE	RMSE < .08	.078
Incremental fit	CFI	CFI > .90	.987
	TLI	TLI > .90	.972
	NFI	NFI > .90	.967
Parsimonious fit	χ^2/df	χ^2/df < 5.0	χ^2/df = 2.85 < 5.0

Table 7. Categories of standards for judging practices

Mean	Practice level
1.0-1.8	Very low
1.81-2.6	Low
2.61-3.41	Medium
3.42-4.22	High
4.23-5.0	Very high

RESULTS

Based on the review of the literature and previous studies that addressed STEM standards, and evaluated the performance and teaching practices of teachers, this study identified a list of teaching practices consistent with STEM standards, thus answering the first research question: What are the teaching practices required for mathematics teachers of gifted students in the intermediate stage consistent with STEM standards?

To answer the second question, concerning the level of implementation of teaching practices consistent with STEM standards by mathematics teachers of gifted students in class, we calculated the arithmetic means and standard deviations for the scores of the research sample. Table 7 shows the scale we used to judge the teachers' practice level using the scores for the five-point Likert-type scale of the observation scorecard. The range is calculated where 5 – 1 = 4. The length of a category was calculated by dividing the range by the number of categories or options, then 4 / 5 = 0.80.

Table 8 shows the results of the evaluation of the level of mathematics teachers' practices in planning, implementation, and evaluation based on STEM standards.

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Table 8. Results of evaluating the teaching practices of mathematics teachers in the three dimensions according to STEM standards

	Teaching practices	Mean	Standard Deviation	Practice Level
1	Determine the cognitive, skills-based, and emotional needs of learners to meet STEM standards	2.56	1.21	Low
2	Plan educational objectives in a way that shows the integration of mathematics, science, engineering, and technology	2.71	1.34	Medium
3	Organize the content in a way that shows integration between mathematics, science, engineering, and technology	2.83	1.62	Medium
4	Plan content in a problem-solving manner to suit the level of learners	3.27	1.15	Medium
5	Plan and design lessons to achieve the objectives of STEM education, such as: developing thinking and technological skills, encouraging teamwork, communication, scientific investigation, scientific experimentation, self-learning, and technological and engineering design	2.87	1.53	Medium
6	Determine various appropriate teaching strategies for STEM education, such as: scientific inquiry, problem-solving, self-learning, active learning, metacognition, differentiated learning, play-based learning (e.g., using robots and Lego), project-based learning, brainstorming, experimentation, scientific reasoning, cognitive journeys, learning cycles	2.84	1.37	Medium
7	Design enrichment, investigative and exploratory activities	3.15	1.25	Medium
8	Plan engineering designs to solve problems in mathematics	2.60	1.26	Low
9	Plan educational situations that link the content of science, technology, engineering, and mathematics to the reality of the learners' lives	2.72	1.33	Medium
10	Plan for learner-centered learning and consider individual differences among learners	3.19	1.38	Medium
11	Plan project-based learning	3.25	1.28	Medium
12	Ensure diversification in the design and selection of tools and methods for evaluating the knowledge, skills, and attitudes of learners, such as: achievement tests, thinking tests, achievement profiles, attitude and tendency measures, diagnostic concept tests, performance measures, self-evaluation, and peer evaluation	2.91	1.26	Medium
13	Plan to use the different types of calendars (tribal, formative, and final)	3.40	1.28	Medium
14	Plan to evaluate different aspects of learning sciences (cognitive, skills-based, and emotional)	3.34	1.31	Medium
15	Plan investigative tasks that can be carried out by learners at home through research and the use of technological means in various fields of knowledge (the Internet, scientific books, and scientific journals)	2.99	1.22	Medium
16	Raise exciting questions that help recall previous knowledge, and link and explore relationships between different sciences	3.26	1.25	Medium
17	Provide an environment based on exploring knowledge from a variety of sources, and conducive to design and innovation	3.11	1.23	Medium
Creative planning for teaching consistent with STEM education		**3.00**	**1.31**	**Medium**
1	Prepare for teaching mathematics using a variety of methods suitable for STEM education, such as: a puzzling question, a problem related to students' lives, some contradictions, real events, stories, or open-ended questions. Aim to arouse learners' interest, increase their motivation, and draw their attention to the new lesson	3.09	1.40	Medium
2	Ask questions that determine the learners' previous experiences related to the subject of the lesson and develop scientific thinking	3.61	1.25	High
3	Allow students the freedom to discuss and exchange ideas through the process of research and inquiry	3.54	1.30	High
4	Employ cooperative learning methods consistent with STEM education	2.94	1.47	Medium
5	Employ methods of communicating with the community consistent with STEM education	2.97	1.36	Medium
6	Employ scientific investigation consistent with STEM education	2.82	1.37	Medium
7	Employ engineering design consistent with STEM education	2.41	1.22	Low
8	Employ problem-centered learning consistent with STEM education	3.29	1.39	Medium
9	Employ learner-centered learning consistent with STEM education	2.75	1.51	Medium
10	Employ learning based on applied and technological projects	2.97	1.39	Medium
11	Direct the students toward the implementation of enrichment, investigative and exploratory activities	3.14	1.35	Medium
12	Develop 21st-century skills (creative thinking skills, critical thinking skills, life skills, cooperation and communication skills, vocational skills, and technological skills) among learners	3.33	1.32	Medium

Table 8 (Continued).

	Teaching practices	Mean	Standard Deviation	Practice Level
13	Provide scientific and technological tools and resources to help learners solve problems	2.84	1.48	Medium
14	Create an interactive learning environment that helps research and investigation through a range of activities (investigative activities, discovery and experimentation, and cooperative learning)	3.07	1.36	Medium
15	Take into account individual differences among students in the teaching and learning process	3.36	1.52	Medium
16	Use audio and visual samples related to the reality of the learner and employ tools and equipment	3.41	1.40	Medium
17	Develop research skills and provoke ideas and solutions	3.12	1.34	Medium
18	Scientifically answer the learners' questions	3.40	1.28	Medium
Implementation of creative teaching consistent with STEM education		**3.10**	**1.38**	**Medium**
1	Use performance-based continuous assessment consistent with STEM education	2.92	1.49	Medium
2	Use pre-, constructive, and summative assessment types in teaching consistent with STEM education to verify cognitive growth and learning continuity	2.98	1.24	Medium
3	Use types of delayed and immediate feedback when teaching consistent with STEM education	3.15	1.38	Medium
4	Use various evaluation methods and tools in evaluating learners' learning (achievement tests, reasoning tests, achievement profile, attitude and tendency measures, diagnostic concept tests, performance measures, self-evaluation, peer evaluation) consistent with STEM education	3.14	1.19	Medium
5	Use electronic evaluation methods (electronic achievement files, short tests, discussion boards, blogs, interactive worksheets) consistent with STEM education	2.89	1.40	Medium
6	Diagnose learners' strengths in learning mathematics consistent with STEM education	3.06	1.35	Medium
7	Enhance learners' strengths in learning mathematics consistent with STEM education	2.86	1.29	Medium
8	Diagnose weaknesses in learning mathematics among learners consistent with STEM education	2.97	1.28	Medium
9	Address deficiencies in learners' learning of mathematics consistent with STEM education	2.99	1.38	Medium
10	Use methods to ensure the correctness of the solution in mathematical problems	3.37	1.32	Medium
11	Measure students' abilities to think scientifically consistent with STEM education	2.34	1.46	Low
Holistic assessment based on STEM education		**2.97**	**1.33**	**Medium**

Table 8 shows the overall arithmetic means and standard deviations for the level of teaching practices in the three dimensions, as follows: Planning: The mean (M) for the planning dimension is 3.00, and the standard deviation (SD) is 1.31. This indicates that, on average, the level of planning in teaching practices is moderate, with some variability among the participants. The values suggest that the participants have an average level of proficiency in the planning aspect of teaching. Implementation: The mean (M) for the implementation dimension is 3.10, and the standard deviation (SD) is 1.38. This indicates that, on average, the level of implementation in teaching practices is slightly higher than the planning dimension. However, there is still variability among the participants. The values suggest that the participants have an average level of proficiency in implementing teaching practices. Evaluation: The mean (M) for the evaluation dimension is 2.97, and the standard deviation (SD) is 1.33. This indicates that, on average, the level of evaluation in teaching practices is similar to the planning dimension. However, there is still variability among the participants. The values suggest that the participants have an average level of proficiency in evaluating teaching practices. These values indicate an average level of practice.

In the evaluation of teaching practices within the dimensions of planning, implementation, and evaluation based on STEM standards, specific teaching practices were assessed for their performance levels.

In the planning dimension, two teaching practices received poor ratings:

- Practice No. 1 (M = 2.56) focused on determining the cognitive, skills-based, and emotional needs of learners to meet STEM standards.
- Practice No. 3 (M = 2.60) involved organizing content to demonstrate integration between mathematics, science, engineering, and technology.

Other teaching practices in the planning dimension had mean scores ranging from 2.71 to 3.40, indicating an average level of performance.

Moving to the implementation dimension, the practice with the lowest performance rating was:

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- Practice No. 7 (M = 2.41), which related to employing engineering design consistent with STEM education.

Conversely, two practices demonstrated high levels of performance:

- Practice No. 2 (M = 3.61), involving asking questions to assess learners' previous experiences related to the subject of the lesson and develop scientific thinking.
- Practice No. 3 (M = 3.54), allowing students the freedom to discuss and exchange ideas through research and inquiry.

All other practices within the implementation dimension had mean scores ranging from 2.75 to 3.41, indicating an average level of performance.

Finally, within the evaluation dimension, one teaching practice was rated as poor:

- Practice No. 7 (M = 2.34), focusing on enhancing learners' strengths in learning mathematics consistent with STEM education.

The remaining teaching practices in the evaluation dimension had mean scores ranging from 2.86 to 3.37, representing average performance levels. These assessments provide insights into the effectiveness and areas for improvement of teaching practices aligned with STEM standards.

DISCUSSION

It is clear from the results that the practice and performance of mathematics teachers of gifted students in teaching according to STEM standards was average over the semester for all three dimensions: preparation of teaching, implementation of teaching, and evaluation of learning. This indicates weaknesses in the teaching of mathematics for gifted students.

The results show that the teachers' creative planning for teaching in accordance with STEM standards was average. This may have been due to the teachers not fully knowing or understanding the preparation strategies for teaching to achieve integration and interdependence between the sciences, including providing an appropriate learning environment or defining teaching objectives that achieve integration. This could be related to the weaknesses in training provision and a lack of awareness-raising in seminars and scientific conferences concerning planning for teaching mathematics consistent with STEM standards. This result is in line with the study conducted by Koussa and Bayones (2019), which found only medium-level teaching competencies among female mathematics teachers in Makkah Al-Mukarramah regarding planning based on the integrated STEM approach. Moreover, the study by Tschannen-Moran and Hoy (2001) found that teacher self-efficacy can have a significant impact on teacher performance and student achievement in STEM subjects. While Hamdi (2017) found that chemistry teachers' implementation of teaching strategies with regard to STEM-oriented preparation was generally weak.

Similarly, the results for the implementation dimension were average. This likely reflects their lack of awareness of appropriate teaching strategies and methods for integrating of mathematics with other subjects, including identifying common concepts between STEM branches, thus leading to the failure to engage in activities in or outside class that call for integration. Again, the lack of training in how to implement mathematics teaching consistent with STEM standards is an issue, indicating a weak connection of programs with the contemporary global trends in teaching mathematics aimed at developing 22nd-century skills and integrating scientific and engineering practices. There is a need to raise teachers' awareness of the importance of implementing mathematics teaching that is congruent with STEM education. This result is consistent with the results of Salamat and Al-Shehri (2016), who found an average level of teaching performance among teachers. As in this study, Omar and Al-Qahtani (2022), Abdel-Raouf (2017), and Al-Hutaibi (2018) identified the need to improve the teaching performance of mathematics teachers in line with modern trends in teaching and learning, such as STEM education. Also, Banilower et al. (2013) found that professional development programs that focus on STEM content and pedagogy can improve teachers' knowledge and skills, which can positively impact student achievement. In contrast to this study, however, Koussa and Ba-Yones (2019) found high teaching competencies among female mathematics teachers in Makkah Al-Mukarramah in terms of implementing STEM-based teaching, while Al-Rouqi (2018), Al-Siyabiya and Ambo Saidi (2018), and Hamdi (2017) reported that the level of teaching performance in their studies was generally weak. It is logical that there are differences between the results of this study and those of some previous works as they differ in many respects, such as the research sample, the teachers' characteristics, their capabilities, the different resources and material equipment, and the professional development cycles. As Affouneh et al. (2020) showed, various factors affect the professional development of teachers with regard to STEM education, including personal characteristics and internal factors, represented in attitudes and beliefs regarding STEM-based professional development activities, and teachers' assessments, in addition to external factors, such as the design of training programs, availability of training materials, and timing of training.

For the third and final dimension, evaluation of learning, the results were also average. We again attribute this weakness to the teachers' lack of knowledge of appropriate evaluation strategies to ensure that students have a grasp of scientific concepts reflecting an integrated perspective or to verify problem-solving. Moreover, they lack awareness of new evaluation methods such as electronic evaluation and the use of alternative assessment strategies and tools in teaching mathematics (observational assessment, communicative assessment, performance-based assessment, self-assessment, and pen-and-paper assessment). Where the study by Chien and Chu (2018) aimed at evaluating different learning outcomes according to the design of the STEAM curriculum and emphasized the importance of diversity in the use of different assessment tools such as assessment of cognitive aspects, design drafts, group discussion records, correction, and improvement discussion records. These issues reflect the absence of scientific seminars and conferences aimed at raising teachers' awareness of the importance of assessment consistent with STEM standards and how to conduct it.

Overall, the results point to a lack of formal education designed in accordance with the STEM approach in the Kingdom of Saudi Arabia, the teachers' lack of awareness of STEM education and its requirements despite their educational experience, and poor training on the nature of STEM curricula. Teachers need training that addresses the standards of these curricula and how to teach them using appropriate teaching strategies. They also lack the different tools and techniques needed for self-reflection and group reflection, such as peer coaching and achievement profiles.

Applying STEM education imposes demands related to curricula, the students, and the professional development of teachers and requires the cooperation of all parties involved in the school, including the administration, teachers, and students. In addition, educational activities based on the STEM approach place an academic burden on mathematics teachers, as they require sufficient time to design activities and projects that can achieve integration between mathematics concepts and related concepts in science, engineering, and technology. Some previous studies have indicated that teachers do not have enough time to plan, implement and evaluate lessons in line with STEM standards. Another issue identified is poor cooperation with teachers of other subjects in organizing and planning existing and overlapping lessons, leading to poor application of lessons according to STEM standards. In this regard, there is a dearth of supportive programs that allow teachers to cooperate, exchange experiences, and plan lessons in an integrated manner (Al-Dosari, 2015; Moore et al., 2014). Teachers may also lack interest in engaging with scientific and engineering knowledge or not have the necessary skills to make the link since the approach thus far has been to teach the sciences separately. Finally, the results also point to the failure of pre-service mathematics teacher preparation programs to address concepts related to the STEM approach.

Overall, the analysis and findings show that the mathematics teachers of gifted students in this study were still broadly practicing the traditional approach to teaching, which relies on the teacher as a source of knowledge. In addition, it is likely that the developers of the curriculum did not design it with reference to STEM standards per se, but to several international trends. To fulfill the ambitions of the Saudi Vision 2030, the Ministry of Education (2019) has highlighted the need to develop advanced educational curricula that focus on basic skills in addition to developing talents and building character. The implementation of STEM education is likely hindered by the fact that the mathematics curriculum design team works independently of the computing, science, and educational technology curriculum design team. They need the skills to strategically integrate and include technological skills. To this end, the teams writing curricula for mathematics, science, technology, and engineering must be brought together to work cooperatively on an integrated approach consistent with STEM standards.

CONCLUSION AND RECOMMENDATIONS

The STEM approach recognizes that gifted students require a variety of factors to achieve their full potential. These factors encompass self-directed learning, fairness and equity, respect and recognition, social awareness, scientific exploration, technological resources, guidance and counseling, family support, a positive environment, scientific culture, language and communication, and others. To support students gifted in STEM fields and enable their success, schools, educators, scientific communities, and governments must collaborate to provide these factors and create an appropriate environment. Moreover, teachers who employ the STEM approach must possess the necessary skills and expertise to deliver high-quality education and motivate students to learn and innovate in STEM fields. This requires deep knowledge in these areas, personalized instruction, guidance, motivation to challenge and innovate, adeptness in technology, continuous learning and development. As STEM is a contemporary approach to education, developing teachers' competencies in this area is critical to its success.

The study's findings indicate that the implementation of teaching practices for mathematics teachers in accordance with STEM standards is not reaching the required levels for effective instruction of gifted students. Given the Kingdom of Saudi Arabia's significant investment in gifted education to develop students' abilities and talents, ongoing evaluation of mathematics teachers' creative teaching practices for gifted students is vital for improving the quality of instruction in this area. It is imperative to prioritize the development and improvement

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of teaching practices for mathematics teachers to ensure they align with STEM standards and enhance the learning outcomes of gifted students in the Kingdom.

The moderate level of implementation of STEM-aligned teaching practices for gifted students is concerning because it signifies a missed opportunity to fully leverage the potential benefits of STEM education in this specific context. When teaching practices only achieve a moderate level of alignment with STEM standards, gifted students may not experience the depth of engagement, interdisciplinary connections, and problem-solving opportunities that are crucial for their optimal development. This limited implementation could lead to missed opportunities for enhancing critical and innovative thinking, as well as real-world problem-solving abilities—skills that are fundamental for success in STEM fields. Moreover, without achieving higher levels of alignment, gifted students may not fully realize their potential or be adequately prepared for advanced studies and careers in STEM disciplines. The consequences of this imbalance include a potential mismatch between the skills required in the STEM workforce and the abilities of gifted students who have not received optimal STEM education experiences. Therefore, enhancing the alignment between teaching practices and STEM standards is imperative to maximize educational outcomes and future prospects for gifted students in Saudi Arabia and globally. Continuous assessment and development of teaching practices are crucial steps toward achieving this goal and ensuring that gifted students receive the support and opportunities necessary to thrive in STEM fields.

The findings of this study emphasize the significance of aligning teaching practices with STEM standards to optimize educational outcomes for gifted students. Integrating principles from science, technology, engineering, and mathematics (STEM) into mathematics education enables teachers to design more engaging and innovative learning experiences that cultivate critical thinking, problem-solving abilities, and interdisciplinary communication. This alignment not only enhances student engagement and motivation but also equips talented individuals with the skills and knowledge necessary for future careers in STEM fields, providing them with authentic and meaningful educational pathways. Additionally, enhancing the alignment between teaching practices and STEM standards fosters equity and inclusivity in gifted education, ensuring that all students, regardless of background or location, have access to high-quality STEM educational experiences. Ultimately, these improvements could lead to more effective and equitable educational outcomes for gifted students, preparing them for success in an increasingly STEM-focused world.

After a comprehensive review and discussion of the study's results, a series of recommendations has been developed. Firstly, it is essential to increase awareness of STEM education among mathematics teachers. Secondly, incorporating STEM topics and teaching strategies into pre-service teacher preparation programs is recommended. Thirdly, effective training programs should be designed and implemented for middle school mathematics teachers to develop their teaching practices and align performance with STEM standards across learning planning, implementation, and evaluation domains. Fourthly, integrating topics related to scientific and technological developments into mathematics curricula is advised. Fifthly, adopting the observation scorecard used in this study and disseminating it to mathematics supervisors of gifted students across the Kingdom of Saudi Arabia is recommended. Sixthly, designing an integrated website that caters to researchers and others interested in directing science, technology, engineering, and mathematics (STEM) efforts could be beneficial. Seventhly, enhancing communication between curriculum developers and scientific research centers is crucial to facilitate the integration of STEM education into mathematics teaching. Eighthly, providing the necessary infrastructure and technology in public schools to support STEM approaches is recommended. Lastly, creating comprehensive guides and resources specifically tailored for mathematics teachers can offer practical strategies and tools for implementing integrated STEM curricula and enhancing teaching practices. These measures collectively aim to improve the alignment between teaching practices and STEM standards, ultimately enhancing mathematics education quality and preparing students for success in STEM fields.

Limitations and Future Work

The study acknowledges several limitations that could have impacted the results, particularly in the context of implementing STEM-aligned teaching practices for gifted students. One notable limitation is the sample size, which may not have adequately represented the diversity or range of mathematics teachers specializing in gifted education. Additionally, the observation process employed to evaluate teaching practices might have introduced biases or limitations concerning the accuracy and comprehensiveness of data collection. Various contextual factors, such as the specific setting or circumstances in which the observations occurred, could have influenced the observed teaching practices and their alignment with STEM standards. Moreover, potential biases related to participant selection or criteria used for evaluating teaching practices may have influenced the study outcomes. To address these limitations, future research should focus on employing larger and more diverse samples, enhancing observational methodologies, and implementing robust measures to mitigate biases and enhance the generalizability of findings in assessing STEM-aligned teaching practices for gifted students.

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There are multiple potential future directions for evaluating the creative teaching practices of mathematics teachers for gifted students in accordance with STEM criteria. One approach is to leverage technology to create digital portfolios that showcase both students' work and teachers' teaching methods. Through analyzing these portfolios, valuable insights can be gained into the effectiveness of different teaching strategies, and areas for improvement can be identified. Another potential direction could be the adoption of observation protocols to assess the teaching practices of mathematics teachers for gifted students. The data collected from these observations can be utilized to identify effective teaching practices and provide constructive feedback to teachers.

In future studies aimed at addressing the identified challenges and improving STEM-aligned teaching practices, several key areas of investigation can be explored: Impact of Professional Development Programs: Research can delve into assessing how professional development programs specifically designed for mathematics teachers contribute to effectively implementing STEM standards in teaching practices for gifted students. Understanding the influence of targeted training and development on teacher competency in STEM education is crucial. Effectiveness of Technology-Based Tools and Resources: Further exploration can focus on evaluating the effectiveness of technology-based tools and resources, such as digital simulations and virtual aids, in fostering creative thinking and problem-solving skills among gifted students. This research can provide insights into leveraging technology to enhance learning outcomes. Collaboration Among Teachers: Investigating the impact of collaborative efforts among teachers on the development of effective teaching practices for gifted mathematics education can offer valuable insights. Studying successful models of teacher collaboration can inform best practices in interdisciplinary STEM education. Cultural and Linguistic Diversity: Exploring how cultural and linguistic diversity influences the teaching practices of mathematics educators working with gifted STEM students can be informative. Understanding the unique challenges and opportunities presented by diverse student populations can guide the development of inclusive and effective teaching approaches. Development of Assessment Methods: Developing and validating assessment methods and tools specifically tailored to evaluate the effectiveness of teaching practices for gifted mathematics educators is essential. This area of research can contribute to establishing robust evaluation frameworks for STEM-aligned teaching practices.

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